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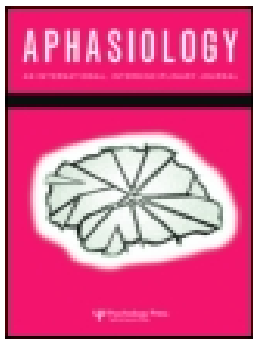
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## Bilingualism and the severity of poststroke aphasia

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### ABSTRACT

**Background:** Bilingualism has been associated with cognitive benefits in healthy people as well as in patients with cognitive impairment due to stroke and dementia. However, the relationship between bilingualism and aphasia is more complex. While bilinguals are as likely as monolinguals to develop aphasia after stroke, studies of relationship between bilingualism and severity of post-stroke language recovery are few and have produced conflicting results, with much evidence derived from immigrant populations or small case series.

**Aims:** Against this background of limited number of studies, we set out to explore the relationship between bilingualism and severity of language impairment in stroke aphasia. We explored the hypothesis that enhanced cognitive abilities related to bilingualism may have a positive impact on recovery from aphasia.

**Methods & Procedures:** We investigated 38 bilingual and 27 monolingual patients who participated in a longitudinal hospital-based stroke registry and were evaluated at least 3 months after stroke (mean 11.5 months). Patient performance on language and other cognitive functions was evaluated with Addenbrooke's Cognitive Examination – Revised (ACE-R) validated for use in aphasia in local languages and for varying educational levels. The results of monolinguals and bilinguals were compared after accounting for confounding variables, including age, gender, education, occupation, medical, and stroke characteristics.

**Outcomes & Results:** Aphasia severity as measured by the language domain sub-scores (total of language and fluency scores) of ACE-R was significantly higher in monolinguals compared with bilinguals (7.0 vs. 14.4, maximum score 40;  $p = 0.008$ , effect size =  $-0.691$ ). Bilinguals performed significantly better than their monolingual counterparts in attention, memory, and visuospatial domains of ACE-R. A univariate general linear model analysis showed that bilingualism was significantly associated with higher language domain scores of ACE-R after adjusting for other confounding variables.

**Conclusions:** The results suggest that although bilingual speakers are at equal risk of developing aphasia after stroke as monolingual ones, their aphasia is likely to be less severe.

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## Introduction

While the effect of bilingualism on cognitive functions is complex and its nature still being debated, a large number of studies have reported enhanced executive functions in bilingual healthy speakers (e.g., Adesope, Lavin, Thompson, & Ungerleider, 2010; Bialystok, Craik, & Luk, 2012; Guzmán-Vélez & Tranel, 2015; Perani & Abutalebi, 2015), and even if controlled for baseline childhood intelligence (Bak, Nissan, Allerhand, & Deary, 2014). This beneficial effect is found to extend to cognitive disorders too. Bilingualism was associated with a 4–6-year delay in age at onset of dementia and its subtypes (Alladi et al., 2013, 2017; Craik, Bialystok, & Freedman, 2010; Woumans et al., 2015). A recent study demonstrated that bilingualism was also associated with a significantly better cognitive outcome in stroke patients (Alladi et al., 2016). This apparent protective effect is thought to be conferred by the lifelong practice of using two languages and switching between them, while inhibiting the potential competitors during production (Green, 1998). It has been suggested that the interactional contexts bilinguals find themselves in single language, dual language, and code-switching, lead them to adapt various cognitive control processes that result in efficient use of control networks (Green & Abutalebi, 2013). The bilingual advantage in cognitive functioning has been supported by demonstration of enhanced frontal connectivity and neural reserve in bilinguals with dementia (Perani et al., 2017).

Studies on bilingualism have been conducted mainly in western populations where bilingual speakers consisted of predominantly immigrants compared to the monolingual autochthonous population (Bialystok, Craik, & Freedman, 2007; Craik et al., 2010; Schweizer, Ware, Fischer, Craik, & Bialystok, 2012). Studying populations where bilingualism is not related to immigration will make it possible to disentangle the phenomenon of bilingualism from the effects of immigration (Alladi et al., 2013). Such a situation exists in India; a country characterized by an exceptional linguistic diversity and bilingualism is widely prevalent for several centuries in its population (Vasanta, Suvarna, Sireesha, & Raju, 2010). In Hyderabad, as in much of Southern India, neighborhood or contact multi/bilingualism is a characteristic feature resulting from inter-cultural, inter-group interactions. Similar to immigration, it is recognized that education can also be a potential confounding factor for effect of bilingualism on cognitive reserve (Grant, Dennis, & Li, 2014). In India, it is possible to separate the effects of bilingualism and education, since bilingualism is not necessarily linked to education as illiteracy is still commonly encountered among both monolinguals and bilinguals (Census of India, 2011).

The effects of bilingualism on language functions and language disorders have been less consistent. Studies in healthy adults and children report a bilingual cost to verbal fluency, comprehension, and picture naming (Bialystok, Craik, Green, & Gollan, 2009) with the delay in lexical access explicitly linked to active bilingual language use (de Bruin, Della Sala, & Bak, 2016). Literature suggests that bilinguals generally perform poorer than monolinguals on the semantic fluency task (e.g., Gollan, Montoya, & Werner, 2002; Portocarrero, Burright, & Donovan, 2007) but outperform monolinguals on the letter fluency task because of their higher executive functions (Bialystok, Craik, & Luk, 2008).

Studies on bilingual effects on language disorders suggest a complex pattern. In a stroke cohort, the frequency of aphasia did not differ between bilinguals and monolinguals (Alladi et al., 2016) and there was no delay in the onset of progressive aphasia

variants of frontotemporal dementia in bilinguals compared to monolinguals (Alladi et al., 2017). Studying the relationship between bilingualism and conversational output, Penn, Frankel, Watermeyer, and Russell (2010) showed that bilingual speakers with aphasia demonstrated superior conversational skills, correlating with retained executive functions compared to monolinguals. In this study where bilinguals were tested in English which was their proficient language, strong conversational strategies such as topic control and initiation, repair, and conversational flexibility in bilingual speakers with aphasia were therefore considered to be linked to their profile of cognitive flexibility, whereas the conversational output in monolingual speakers was scattered and inconsistently correlated with their executive functions. The role of nonlinguistic abilities in influencing language outcome in aphasia has been demonstrated in earlier studies. Vukovic, Vuksanovic, and Vukovic (2008) and Seniów, Litwin, and Leśniak (2009) studied verbal fluency, auditory comprehension, repetition, and confrontation naming in individuals with aphasia and found performance on these tasks to be positively influenced by nonlinguistic cognitive abilities such as reasoning and verbal memory.

In contrast to the study by Penn et al., in their study of stroke aphasia, Hope and colleagues (2015) found that bilingual non-native English speakers with aphasia (who were all immigrants) performed worse on a range of language tasks administered both in English and in their native language compared to monolingual native English-speaking individuals with aphasia. The authors attributed their findings to poor premorbid language proficiency in bilinguals compared to monolinguals and suggested that bilinguals are more sensitive to lesion-deficit associations in the brain.

Against this background of limited number of studies, there is a need for further exploration of the nature of the relationship between bilingualism vs. monolingualism and the severity of language impairment in aphasia. This study aimed to investigate this association, in a cohort of individuals with stroke aphasia recruited from a large population of stroke patients from Hyderabad, India. Bilingualism in India is part of daily life across socioeconomic and educational levels, and is not associated with immigration, hence avoiding the major confounds of bilingualism studies in the Western World (Bak & Alladi, 2016). We explored the hypothesis that enhanced cognitive abilities related to bilingualism may have a positive impact on language function recovery in stroke aphasia, once the confounding factors such as age, education, and immigration are accounted for.

## Methods

### *Patient recruitment*

The study cohort consisted a total of 68 cases of ischemic stroke patients with a clinical diagnosis of aphasia (the details of diagnosis and classification of aphasia discussed in more detail later), who were participants in the Stroke Registry of Nizam's Institute of Medical Sciences, established to study clinical profile and outcome in consecutive cases of acute stroke (Alladi et al., 2016; Kaul et al., 2002). Patients with ischemic stroke, older than 18 years and evaluated at least 3 months after stroke during the period 2006–2013, were included. All patients underwent a systematic demographic, medical, neurological, and radiological evaluation for stroke

characteristics, including time after stroke, the location and laterality of infarcts, and history of prior stroke. Evaluation was done according to a standard protocol, by neurologists certified in stroke diagnosis and care. Patients were subsequently referred to the memory clinic and evaluated with a cognitive assessment using a structured diagnostic protocol adapted from the Cambridge Memory Clinic model (Alladi et al., 2011; Hodges, Berrios, & Breen, 2000).

### ***Cognitive and language evaluation***

Cognitive and language evaluation was conducted using Addenbrooke's Cognitive Examination – Revised (ACE-R), a widely used, multidimensional cognitive screening tool with a maximum score of 100 points. It assesses (with the provision of domain-wise composite scores) five cognitive domains: attention and orientation, memory, fluency, language, and visuospatial abilities. The sub-components of language subtest consist of tests of comprehension, naming, pointing to description, repetition, reading, and writing; the verbal fluency sub-score is the combination of animal and letter fluency scores, and the language subscore has been used to detect and monitor evolution of language and cognitive impairment in primary progressive aphasia, including fluent and nonfluent aphasia (Leyton, Hornberger, Mioshi, & Hodges, 2010). ACE-R has been validated in large studies of stroke outcome (Pendlebury, Mariz, Bull, Mehta, & Rothwell, 2012) and has been found to be a useful tool in diagnosis of aphasia in stroke (Gaber, Parsons, & Gautam, 2011).

In India, the Addenbrooke's Cognitive Examination has been validated in Malayalam (the official language of the province of Kerala, a Dravidian language related to Telugu, spoken in Hyderabad) (Mathuranath et al., 2004), and the revised version of ACE-R has been adapted and validated for use in local languages of Hyderabad: Telugu, Dakhini, and Hindi for both literate and illiterate populations (Alladi et al., 2016). The process of adaptation included culturally appropriate modifications of the original English version. Moreover, ACE-R was adapted for the illiterate population by modifying literacy-dependent items (Alladi et al., 2015). Translations and back translations, and pilot testing were done based on standard procedures. This data has been in use at the memory clinic for diagnosis of dementia and mild cognitive impairment in previous studies (Alladi et al., 2016, 2011).

The diagnosis of aphasia and severity was made by two experienced behavioral neurologists (S.A. and S.K.), trained psychologists, and speech and language pathologists by obtaining a detailed history for language deficits and assessment of language through a clinical interview supported by language subscores of ACE-R. Clinical evaluation consisted of a conversational interview, testing for comprehension using simple closed set questions, pointing, following instructions, and spoken speech, object naming and production of simple sentences. The inadequate or inappropriate use of language such as paraphasias, circumlocutions, jargon, and aggramatism was observed. ACE-R language subscores were also reviewed to arrive at a diagnosis of aphasia and its severity, with lower scores suggesting higher severity. Patients were tested in their mother tongue, which was the predominant language of use, and the language used to diagnose aphasia.

### ***Educational status***

Number of years of formal education was recorded in all subjects. Patients were also classified as literates and illiterates. Illiterates were defined as those who had no formal education and were unable to read and write in any language, a definition based on Census operations of India (Census of India, 1961).

### ***Occupational status***

The National Classification of Occupations (2004), developed by the Ministry of Labour of India, was used to identify different occupations within the cohort (NCO, 2004). The NCO defines several occupational categories that can be grouped into elementary, skilled and professionals based on skill levels. We used the occupational category as a proxy measure of socioeconomic status in the study.

### ***Language status***

In Hyderabad, language profile and use has been studied systematically (Vasanta, 2011; Vasanta et al., 2010). Telugu is the predominant local language, spoken by majority Hindu community as their mother tongue, followed by Dakkhini spoken by the minority community of Muslims. English in Hyderabad is used predominantly in educational, administrative, and media settings. Additionally, Hindi is spoken as the official national language and is taught at school level. The language combinations of bilinguals are typically combinations of Telugu or Dakkhini as the predominant language of use and Hindi and/or English (Vasanta et al., 2010). There is a smaller proportion of monolinguals in the community, especially those residing in predominantly monolingual Telugu-speaking regions, both within Hyderabad and from regions outside the multicultural city of Hyderabad.

In this study, bilingualism was defined as the ability to communicate in two or more languages in interaction with other speakers of these same languages (Mohanty, 1994). This definition emphasizes the capacity for active language use over grammatical competence and is hence in line with current notions of bilingualism as lifelong activity rather than passive knowledge (Bak, 2016a). As part of the standard protocol, language history was obtained by interviewing a reliable family member. The mother tongue of each participant, the number of languages spoken fluently by the patient and the ability to communicate in these languages were noted from the interview.

The primary predictor variables were monolingualism and bilingualism, recorded at the time of testing. The outcome variable was the severity of language impairment indicated by the language plus fluency sub-score (hereafter called language domain score) of ACE-R. The potential confounding factors that could affect aphasia severity included demographic characteristics such as age, gender, and stroke characteristics including age at time of stroke, duration after stroke, laterality and location of infarcts, and vascular risk factors including hypertension, diabetes mellitus, cardiac disease, smoking, and chronic alcoholism were recorded. Factors that could potentially confound the relationship between bilingualism and cognition such as education, socioeconomic

status, and number of languages known were also obtained. The Nizam's Institute of Medical Sciences ethics committee approved the study.

### ***Statistical analysis***

Clinical and demographic profiles of monolingual vs. bilingual and literate vs. illiterate groups were compared using independent sample *t*-test for continuous variables and  $\chi^2$  test for categorical variables. Fisher exact test was used when the distribution of the scores is not normal. While comparing ACE-R scores within illiterate group, Kruskal–Wallis, a non-parametric test was performed, as the distribution of the data is not normal. Pearson correlation was used to compare ACE-R language domain score and years of education. A univariate general linear model (GLM) was used to assess the effect of bilingualism on the language domain of ACE-R test after adjusting for various demographic and clinical variables (years of education, gender, age, literacy and duration of stroke). Interaction effects of bilingualism with variables (years of education, gender, age, literacy, and duration of stroke) were also calculated using univariate GLM. Independent *t* tests,  $\chi^2$  test, Fisher exact test, correlation test, and univariate GLM were performed using SPSS 20.0 for Windows software (SPSS Inc., Chicago, IL) and the significance was set at  $p < 0.05$ . Cohen's *d* was calculated to measure the effect sizes for independent *t* tests. Cohen's *d* was computed using R Stat effect size calculator for independent sample *t* tests. Chi-square and Fisher's test effect sizes were measured as Cramer's *V* and computed in SPSS 20.0. As per Cohen's conventions, effect values for  $d \pm 0.20$ ,  $\pm 0.50$ , and  $\pm 0.80$  are recognized thresholds for small, moderate, and large effects, respectively. And for Cramer's *V*,  $\pm 0.10$ ,  $\pm 0.30$ , and  $\pm 0.50$  are recognized thresholds for small, moderate, and large effects, respectively (Cohen, 1988).

## **Results**

### ***General characteristics of the participants with aphasia***

Out of 608 consecutive ischemic stroke patients evaluated during the study period, 68 (11.2%) were diagnosed as aphasia, of whom 65 were included in the present study. Two patients had associated apraxia of speech and one had dysarthria, who were excluded from the analysis. Out of 65 patients, 27 (41.5%) were monolinguals and 38 (58.5%) bilinguals; 49 subjects (75.4%) were male, the mean age of the group at presentation was 54.5 years (range 25–78 years), and the duration of symptoms ranged from 3 to 60 months (mean = 11.5 months).

Of the 27 monolingual speakers, 25 participants spoke Telugu, and one spoke Hindi as their mother tongue (data is not available for 1 subject), and of the 38 bilinguals, Telugu was the mother tongue in 32 speakers (84.2%), Dakhini in 2 speakers (5.3%), and Hindi in 2 speakers (5.3%) (data is not available for 2 subjects).

### ***Comparison of monolingual and bilingual patient groups***

When comparing bilingual and monolingual cohorts for stroke characteristics, age, presence of previous strokes, location and laterality of infarcts, and time after stroke



**Table 1.** Demographic and clinical characteristics of monolingual and bilingual speakers with aphasia.

Sociodemographic factors	Monolinguals ( <i>n</i> = 27)	Bilinguals ( <i>n</i> = 38)	<i>p</i> -Value	Effect size (Cohen <i>d</i> /Cramer's <i>V</i> )
Age (years)	55.5 (11.1)	53.7 (12.3)	0.553	0.150
Education (years)	5.2 (5.4)	11.6 (5.4)	< 0.0001	−1.173
Gender (M:F, %)	17:10 (63.0:37.0)	32:6 (84.2:15.8)	0.583	0.050
Literates	16 (59.3%)	33 (86.8%)	0.018	0.011
Occupation <sup>§</sup>				
Elementary	0	1 (2.9%)	0.583	0.110
Skilled	17 (68.0%)	23 (67.6%)	0.752	0
Professionals	1 (4.0%)	6 (17.6%)	0.230	0.177
Housewife	7 (28.0%)	4 (11.8%)	0.323	0.16
Vascular risk factors				
Hypertension <sup>‡</sup>	15 (62.5%)	19 (52.8%)	0.698	0.039
Diabetes mellitus <sup>‡</sup>	7 (29.2%)	19 (52.8%)	0.245	0.125
Cardiac disease <sup>‡</sup>	5 (20.8%)	4 (11.1%)	0.476	0.106
Smoking <sup>Φ</sup>	9 (37.5%)	6 (17.1%)	0.179	0.156
Chronic alcoholism <sup>Φ</sup>	9 (37.5%)	9 (25.7%)	0.484	0.079
Stroke characteristics				
Time after stroke (months)	12.2 (12.7)	11.0 (15.0)	0.754	0.079
Laterality of infarct <sup>¶</sup>				
Right	0	0	0.791	0.027
Left	16 (80.0%)	26 (89.7%)	0.686	0.109
Bilateral	4 (20.0%)	3 (10.3%)		
Location of infarct <sup>¶</sup>				
Cortical	1 (5%)	3 (10.3%)	0.532	0.085
Subcortical	3 (15%)	5 (17.2%)	0.590	0.022
Cortical-subcortical	16 (80%)	21 (72.4%)	0.823	0.024
Previous stroke <sup>c</sup>	1 (4.2%)	1 (2.7%)	0.640	0.037

<sup>§</sup>Missing data, *n* = 6 (monolingual missing data = 2; bilingual missing data = 4).

<sup>‡</sup>Missing data, *n* = 5 (monolingual missing data = 3; bilingual missing data = 2).

<sup>Φ</sup>Missing data, *n* = 6 (monolingual missing data = 3; bilingual missing data = 3).

<sup>¶</sup>Missing data, *n* = 16 (monolingual missing data = 7; bilingual missing data = 9).

<sup>c</sup>Missing data, *n* = 4 (monolingual missing data = 3; bilingual missing data = 1).

did not differ significantly. The bilingual cohort had more men and higher educational levels compared to the monolingual group, while no difference in occupational status or frequency of vascular risk factors was noted (Table 1). Aphasia severity as measured by the language domain sub-scores (total of language and fluency) of ACE-R was significantly higher in monolinguals compared with bilinguals (7.0 vs, 14.4,  $p = 0.008$ , with an effect size (*d*) of −0.691 which is considered to be moderate) (Table 2). Nonlinguistic cognitive abilities were compared between bilingual and monolingual speakers with aphasia. Bilinguals were found to perform significantly better than their monolingual counterparts in attention ( $p = 0.002$ ,  $d = -0.812$ ), memory ( $p = 0.003$ ,  $d = -0.781$ ), and visuospatial ( $p = 0.004$ ,  $d = -0.761$ ) subtests of the ACE-R (Table 2).

Since education is an important confounding factor for the association between bilingualism and aphasia severity, we evaluated the illiterates separately. A Kruskal–Wallis test showed that there was a statistically significant difference in ACE-R total score and language total scores between the bilingual illiterate speakers ( $n = 5$ ) and monolingual illiterate speakers ( $n = 11$ ). A mean rank of 6.41 for monolingual illiterates and 13.10 for bilingual illiterates was found for ACE-R total score, with  $\chi^2(2) = 6.922$ ,  $p = 0.009$ . A mean rank of 6.82 for monolingual illiterates and 12.20 for bilingual illiterates was found for language total score, with  $\chi^2(2) = 4.465$ ,  $p = 0.035$ . But here, the effect sizes (Cramer's *V*) were found to be small (ACE-R total  $V = 1.4$ , language total  $V = 0.977$ ).

**Table 2.** ACE-R scores of monolingual and bilingual, and literate and illiterate speakers with aphasia.

	Language use			Effect size (Cohen d)	Literacy			Effect size (Cohen d)
	Monolingual ( <i>n</i> = 27)	Bilingual ( <i>n</i> = 38)	<i>p</i> -Value		Illiterate ( <i>n</i> = 16)	Literate ( <i>n</i> = 49)	<i>p</i> -Value	
ACE-R total (total score: 100)	16.7 (23.8)	38.1 (28.0)	0.002	−0.810	28.8 (26.3)	29.3 (29.1)	0.944	−0.020
Attention (max. score: 18)	3.6 (4.8)	8.2 (6.2)	0.002	−0.812	5.7 (4.9)	6.5 (6.4)	0.657	−0.128
Memory (max. score: 26)	3.0 (5.5)	8.5 (7.9)	0.003	−0.781	6.2 (7.0)	6.2 (7.7)	0.994	−0.002
Visuospatial (max. score: 16)	3.1 (4.6)	6.9 (5.3)	0.004	−0.761	4.4 (4.6)	5.7 (5.6)	0.404	−0.242
Fluency (max. score: 14)	1.4 (3.0)	2.6 (2.8)	0.133	−0.383	2.9 (3.3)	1.8 (2.8)	0.184	0.386
Language total (max. score: 26)	5.6 (7.4)	11.9 (9.1)	0.004	−0.754	9.6 (8.1)	9.2 (9.2)	0.878	0.044
Language domain (max. score: 40)	7.0 (10.0)	14.4(11.3)	0.008	−0.691	12.5 (11.1)	11.0 (11.5)	0.644	0.134
Comprehension (max. score: 3)	1.1 (1.3)	1.7 (1.4)	0.062	−0.478	1.4 (1.4)	1.4 (1.4)	0.977	−0.008
Writing (max. score: 2)	0.2 (0.5)	0.3 (0.6)	0.364	−0.230	0.1 (0.3)	0.3 (0.6)	0.270	−0.320
Repetition (max. score: 4)	0.9 (1.3)	1.7 (1.6)	0.033	−0.550	1.6 (1.7)	1.3 (1.5)	0.448	0.220
Naming (max. score: 12)	2.5 (3.9)	5.2 (4.8)	0.020	−0.599	4.4 (4.4)	4.0 (4.7)	0.721	0.103
Pointing (max. score: 4)	0.8 (1.4)	2.3 (1.8)	0.0004	−0.934	1.6 (1.8)	1.7 (1.8)	0.896	−0.038
Reading (max. score: 1)	0.1(0.3)	0.4 (1.5)	0.011	−0.657	0.3 (0.5)	0.3 (0.4)	0.719	0.104

Further, to investigate whether educational status was associated with language severity, we compared language subscores in illiterate and literate subjects. No significant difference was noted in ACE-R total scores and language and other cognitive domain subscores between literates and illiterates (Table 2). Correlation between years of education and language domain was also carried out. The correlation coefficient is 0.037 and *p* value is 0.769, which is not significant.

To study whether bilingualism was independently associated with the severity of aphasia, we performed a univariate GLM analysis. It showed that bilingualism was significantly associated with language domain scores of ACE-R after adjusting for all other variables ( $F_{1, 63} = 9.41, p = 0.003$ ). Other potentially confounding variables such as gender, age, years of education, literacy, and time after stroke did not have a significant association with language domain scores. To assess the effect of interaction between bilingualism and other independent factors on the language domain of the ACE-R, we used univariate GLM. We found no interaction effects of years of education ( $F_{1, 63} = 0.123, p = 0.885$ ), gender ( $F_{1, 63} = 1.900, p = 0.160$ ), age ( $F_{1, 63} = 0.139, p = 0.870$ ), literacy ( $F_{1, 63} = 0.859, p = 0.429$ ), and duration after stroke ( $F_{1, 63} = 2.386, p = 0.102$ ).

## Discussion

Our study examined the association between bilingualism and the severity of stroke aphasia. While the frequency of aphasia following stroke was not different between monolinguals and bilinguals, bilingualism was found to be associated with a lesser severity of aphasia, demonstrated by the higher score on the language domain on ACE-R in bilinguals compared to monolinguals. Our results suggest that, while bilingualism does not change the risk of poststroke aphasia per se, it may have a role in influencing its severity.

Bilinguals and monolinguals were comparable for age, medical, and stroke characteristics known to influence prognosis of stroke aphasia (e.g., Code & Rowley, 1987; Laska, Hellblom, Murray, Kahan, & Von Arbin, 2001; Lendrem & Lincoln, 1985). All participants were evaluated at least three months after stroke, when appreciable recovery tends to have occurred (Demeurisse et al., 1980; Wallesch, Bak, & Schulte-Moenting, 1992). The average time after stroke was comparable between bilinguals and monolinguals, as were other stroke characteristics including infarct location, laterality, and previous strokes. Although bilinguals were overall more educated than monolinguals, the bilingual effect was shown to be independent from education, a factor associated with stroke aphasia recovery (Hillis & Tippett, 2014). Similarly, gender, another variable unequally distributed between the two groups, did not show a significant interaction with bilingualism. Therefore, we hypothesize that the superior executive control mechanisms reported in bilinguals (e.g., Bak, 2016a; Kerrigan, Thomas, Bright, & Filippi, 2016; Valian, 2015) may underlie their improved language outcome. However, future studies that evaluate executive control in a more systematic way will be required to explore this hypothesis.

At the same time, our findings differ from the study by Hope et al. (2015) who found non-native English-speaking bilinguals with aphasia performed poorer on language tests than native English-speaking monolinguals. Several factors might have contributed to these differences. Firstly, the bilingual group in their study consisted largely of immigrants, whereas in our cohort neither monolinguals nor bilinguals were immigrants, reflecting the linguistic demography of Hyderabad, where bilingualism has been characterizing life of most people for many centuries. Secondly, while the bilinguals in the Hope et al. study were reported to be fluent in the languages they spoke, there was little information about the frequency and pattern of native language use. The bilingual group in our study lived in a highly multilingual environment where different languages are used extensively in daily life interactions (Vasanta et al., 2010). This is relevant because language use and exposure has also been found to impact performance on linguistic (de Bruin, Bak, & Della Sala, 2015) and nonlinguistic (de Bruin et al., 2016) tasks as well as affect the pattern of brain activation in studies comparing healthy monolingual and bilinguals (Perani et al., 2003). Thirdly, in their study, comparisons between bilingual and monolingual speakers were made based on performance on English tests. For majority of bilinguals, English was their non-native language while it was the native language for the monolingual speakers. Indeed, the authors comment that while bilingual patients were also tested on language tasks in their native languages, the actual exemplars used for this testing may not have been culturally appropriate. In contrast, in our study, both bilinguals and monolinguals were

tested in their native language, in tests that were adapted for cultural relevance, using age and education matched norms (Alladi et al., 2016). Finally, bilingual speakers in Hope et al. study were a heterogeneous group, speaking more than 20 different first languages and English as their second language. Bilinguals in our study were a more homogeneous group: majority spoke either Telugu or Dakkhini as their native language, often in combination with English and/or Hindi. This is relevant because bilingual populations with differing language combinations may differ in sociocultural and linguistic factors that are known to influence cognitive and language performance (e.g., Abutalebi et al., 2015; Barrett, 2011). Evidence from existing literature indicates that the cognitive and linguistic consequences of bilingualism are dependent on several variables, such as pattern of language use, proficiency, language combination, and language of cognitive testing, giving rise to variability in results across studies conducted in different populations (Bak & Alladi, 2016).

A related finding in bilinguals with aphasia, compared to monolinguals, was the relative preservation of repetition. Repetition is considered to be a multifaceted function and relies on attention, working memory, lexical-semantic, syntactic, and phonological processes. Some studies investigating the neural basis of aphasia underscore the contribution of the right hemisphere and non-damaged arcuate fasciculus to successful repetition (Berthier, Ralph, Pujol, & Green, 2012; Berthier et al., 2013; Rogalsky et al., 2015). Interestingly, in a recent study, increased fractional anisotropy values in the phonological segment of the arcuate fasciculus, as well as a trend toward bilateral structural organization of the arcuate fasciculus was demonstrated in early bilinguals compared to late bilinguals (Hämäläinen, Sairanen, Leminen, & Lehtonen, 2017). Recent imaging findings have also demonstrated a more bilateral organization of anterior cingulate and a larger volume of corpus callosum in bilinguals compared to monolinguals (Felton et al., 2017). It is conceivable, therefore, that a stronger bilateral representation of language as well as modulation of language specific tracts such as the arcuate fasciculus in bilinguals could facilitate aphasia recovery. The cross-sectional nature of our current data does not allow us to test this hypothesis; it would require longitudinal clinical and imaging analysis of the evolution of poststroke aphasia in monolingual and bilingual speakers.

This brings us to the topic of the limitations of our study. Firstly, although all participants underwent CT scan and/or MRI, we were not able to measure the exact size of infarcts due to variability in the available imaging modalities. However, location and laterality of infarcts were studied and no differences were demonstrated between the two language cohorts. Secondly, details of intensity and duration of speech therapy were not available. The majority of participants received advice on a standardized home-based language intervention to improve understanding and expressive skills, according to a standard clinical protocol. Thirdly, the aphasia evaluation was not done using conventional language testing batteries like Western Aphasia Battery or Boston Diagnostic Aphasia Examination; however, the ACE-R has also been widely used to diagnose aphasia due to degenerative disease and in the detection of the fluent variant: semantic dementia and progressive non-fluent aphasia (Leyton et al., 2010) and has also shown good sensitivity and specificity for stroke aphasia diagnosis.

An important limitation of this study is the fact that the applied cognitive and linguistic tests were originally designed with a monolingual English-speaker in mind. This means,

firstly, that with the notable exception of the Bilingual Aphasia Test (Paradis, 1987), most aphasia evaluations are based on the “monolingual default” assumption, which does not reflect the linguistic situation in multilingual societies (Bak & Mehmedbegovic, 2017). Secondly, tests translated and adapted from English might not be optimally designed to capture the specific nature of the languages spoken by patients speaking other languages. As documented in Beveridge and Bak (2011) (and extended to written language in Beveridge & Bak, 2012), the aphasiological literature worldwide is largely based on observations in a small number of linguistically closely related languages, above all English, and to a lesser extent German and Dutch. We have made all efforts to use tests adapted to languages and cultures of our patients, but as pointed out in Bak and Alladi (2016) in the context of bilingualism research, future studies will need to go much further and develop their assessments, classifications, and treatment models from a comparison of different languages rather than from worldwide adaptations of theories and materials based on English.

Another limitation was that bilingualism was defined as a categorical variable. The dynamic nature of bilingual experience and the importance of accounting for age of acquisition, patterns of language use, as well as proficiency in considering cognitive effects of bilingualism have been emphasized. While our definition might appear simplistic, the emphasis on the ability to communicate used in our definition, rather than abstract knowledge, is in line with recent insights about the importance of actual language use in explaining potential bilingualism effects (Bak, 2016). Bilingualism is normative in India, is a part of daily life, and majority of bilinguals speak their second language from childhood. Languages are used interchangeably in personal, informal, and formal interactions and bilingualism is prevalent even among illiterates (Vasanta et al., 2010). Future studies could benefit from longitudinal design, more systematic recording of language acquisition, proficiency and use among individuals with aphasia, more comprehensive language batteries and correlation with neuroimaging.

To conclude, our results suggest that although bilingual speakers are at equal risk of developing aphasia after stroke as monolingual ones (Alladi et al., 2016), their aphasia is likely to be less severe. This effect might reflect not only differences in language processing per se (bilingualism is associated with linguistic costs as well as benefits), but also better nonlinguistic functions (such as attention and executive control), which can facilitate recovery from aphasia.

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